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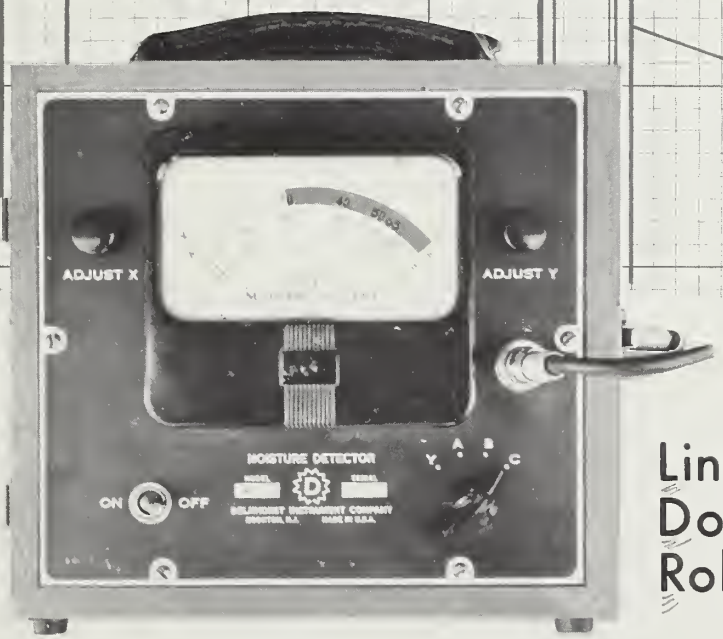
# Moisture Content of Laminated Beams in use In The Rocky Mountain Area



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USDA Forest Service Research Paper RM–73 June 1971
Rocky Mountain Forest and Range Experiment Station
Forest Service U.S. Department of Agriculture

## ABSTRACT

Equilibrium moisture contents were measured seasonally for 3 years in laminated timbers exposed under a variety of interior and exterior conditions in 25 structures from South Dakota to Arizona. Average EMC remained in a relatively narrow, low range of between 6.6 and 10.5 percent. Moisture content did not vary significantly with season of year, vertical location within the cross section of the member, or between interior and exterior exposures. Thus a fabrication moisture content of approximately 8 percent should prove satisfactory for laminated timbers produced for use in the Rocky Mountain region.


Key Words: Laminated wood, lumber seasoning, structural timber.

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# Moisture Content of Laminated Timbers in Use in the Rocky Mountain Area

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Contents

# Moisture Content of Laminated Timbers in Use in the Rocky Mountain Area

Lincoln A. Mueller, Donald C. Markstrom,
and Roland L. Barger

Laminated timbers have long been recognized by architects and engineers for their broad range of architectural and structural design possibilities. Because laminated timbers are also adaptable to the changing quality of the Nation's timber supplies (U.S. Dep. Agr. 1965), considerable effort is warranted to assure a continuing market for this versatile product.

Surface checking of the members after installation has had considerable impact on the market for laminated timbers. While this checking is generally superficial, it has created some customer dissatisfaction and is, therefore, of concern to the industry. Checking most commonly results when the laminated member is fabricated at a moisture content appreciably higher than the equilibrium moisture content (EMC) to which it is exposed in use. The severity of checking is usually proportional to the rate of drying. Ideally, the fabrication moisture content should be approximately the same or perhaps a little under that of the EMC of the area where the timber is to be used (Freas and Selbo 1954).

This study is part of a national effort to develop more complete and accurate information on the moisture content laminated structural members reach under the variety of use conditions common to the various regions in the United States. Such information would make it possible for laminated timber manufacturers to tailor their products more precisely to meet regional moisture conditions.

The overall study was initiated by the Forest Products Laboratory in cooperation with the Southeastern, Pacific Northwest, and Rocky Mountain Forest and Range Experiment Stations. Member firms of the American Institute of Timber Construction also cooperated in the work. A report covering the nationwide aspects of the study has been prepared by the Forest Products Laboratory (Hann et al. 1970), and the Pacific Northwest phase has been reported by Oviatt (1968). This report covers the work within the Rocky Mountain Station area, which extends essentially from Canada to Mexico. Although the area is characterized by a wide range of temperature extremes, precipitation is generally light and the area, as a whole, rates as semiarid to arid.

## Design

In consultation with the various cooperators, a total of 25 structures were selected to provide the laminated timbers for moisture measurements. Structures were chosen to represent a major use for laminated timbers in the area, and one that offered potential for future markets. Structures chosen in the various areas were similar in design and use (exposure class) to eliminate some of the variables and help isolate climatic effects. A number of additional test structures were also included to sample other, and possibly more extreme, exposure conditions in the area.

The types of structures selected, by location and exposure class, are identified in table 1. The exposure classes used were developed by Oviatt (1968) in the Pacific Northwest:

1. Internal normal occupancy—a completely enclosed, heated, and ventilated exposure, such as supermarkets (fig. 1), classrooms, or churches.
2. Exterior protected—an exposure protected from above but fully exposed to normal exterior temperatures and humidities, such as beams under roof overhangs or carports (fig. 2).
3. Exterior exposed—a site fully exposed to all outdoor conditions, such as beam sections extending beyond roofline or crossarms (fig. 2).
4. Special occupancy—one exposed to abnormal conditions such as in freezer plants, or over swimming pools and skating rinks (fig. 3).

The laminated timbers in all but two of the test structures were Douglas-fir. Those in the heated lumber storage building in Denver (structure 9) were of lodgepole pine, while those in the hardware facility in Albuquerque (structure 16) were of southern pine.

Table 1.--Moisture content of laminated timbers in service in the interior and exterior of test structures studied in the Rocky Mountain area

| Structure number | Location | Test structure | Exposure class | Moisture content | | | | Member cross-section | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Average | Standard deviation | Minimum | Maximum | Width | Depth |
| | | | | - - Percent of Oven-dry Weight - - | | | | - Inches - | |
| INTERIOR EXPOSURE | | | | | | | | | |
| 1 | Rapid City, S. Dak. | Supermarket | 1&2 | 6.7 | 0.5 | 6 | 7 | 9 | 31 |
| 2 | | Supermarket | 1&2 | 6.4 | .5 | 6 | 7 | 5 | 21 |
| 3 | Ft. Collins, Colo. | Supermarket | 1&2 | 6.3 | .5 | 6 | 7 | 7 | 24 |
| 4 | | Supermarket | 1&2 | 6.5 | .5 | 6 | 7 | 7 | 22 |
| 5 | | Supermarket | 1 | 7.3 | .6 | 6 | 9 | 7 | 23 |
| 6 | | College dormitory | 1,2&3 | 6.2 | .5 | 5 | 7 | 9 | 30 |
| 7 | Denver and Boulder, Colo. | Supermarket | 1&2 | 6.3 | .5 | 6 | 7 | 5 | 21 |
| 8 | | Supermarket | 1&2 | 6.7 | .7 | 6 | 8 | 9 | 30 |
| 9 | | Hardware store | 1 | 7.1 | .7 | 6 | 9 | 7 | 21 |
| 10 | | Bath house | 1&2 | 7.3 | .5 | 7 | 8 | 3 | 13 |
| 11 | | Heated garage | 1,2&3 | 7.1 | .8 | 6 | 9 | 9 | 41 |
| 12 | | School gymnasium | 1&2 | 7.1 | .7 | 6 | 9 | 7 | 24 |
| 13 | Albuquerque and Los Alamos, N. Mex. | Supermarket | 1&2 | 6.1 | .3 | 6 | 7 | 9 | 18 |
| 14 | | Supermarket | 1&2 | 6.1 | .6 | 5 | 7 | 5 | 24 |
| 15 | | Supermarket | 1 | 6.0 | .4 | 5 | 7 | 9 | 22 |
| 16 | | Lumber store | 1&2 | 6.1 | .6 | 5 | 7 | 6 | 25 |
| 17 | Flagstaff, Ariz. | Supermarket | 1&2 | 6.2 | .6 | 5 | 7 | 7 | 24 |
| 18 | | Supermarket | 1&2 | 7.3 | 1.4 | 6 | 11 | 7 | 24 |
| 19 | | Laboratory | 1&2 | 6.1 | .4 | 5 | 7 | 7 | 13 |
| 20 | | Swimming pool | 2&4 | 9.3 | 1.0 | 7 | 11 | 7 | 24 |
| 21 | Phoenix, Ariz. | Supermarket | 1&2 | 6.2 | .8 | 5 | 7 | 7 | 15 |
| 22 | | Supermarket | 1&2 | 6.7 | .8 | 5 | 9 | 7 | 24 |
| 23 | | Supermarket | 1 | 6.9 | .7 | 6 | 9 | 9 | 23 |
| 24 | | Restaurant | 1&2 | 7.6 | .7 | 6 | 9 | 5 | 16 |
| 25 | | Storage shed | 1 | 7.4 | .7 | 7 | 9 | 7 | 18 |
| EXTERIOR EXPOSURE | | | | | | | | | |
| 1 | Rapid City, S. Dak. | Supermarket | 1&2 | 7.5 | .6 | 6 | 9 | 7 | 18 |
| 2 | | Supermarket | 1&2 | 7.5 | .5 | 7 | 8 | 5 | 20 |
| 3 | Ft. Collins, Colo. | Supermarket | 1&2 | 7.6 | .6 | 7 | 9 | 7 | 24 |
| 4 | | Supermarket | 1&2 | 7.6 | .8 | 6 | 11 | 7 | 22 |
| 5 | | Supermarket | 1 | N | N | N | N | N | N |
| 6 | | College dormitory | 1,2&3 | 8.1 | 2.2 | 7 | 19 | 9 | 30 |
| 7 | Denver and Boulder, Colo. | Supermarket | 1&2 | 7.8 | .9 | 6 | 11 | 5 | 19 |
| 8 | | Supermarket | 1&2 | 7.7 | .8 | 6 | 9 | 7 | 17 |
| 9 | | Hardware store | 1 | N | N | N | N | N | N |
| 10 | | Bath house | 1&2 | 7.8 | 1.5 | 6 | 12 | 3 | 12 |
| 11 | | Heated garage | 1,2&3 | 9.2 | 2.2 | 6 | 15 | 9 | 41 |
| 12 | | School gymnasium | 1&2 | 7.8 | 1.7 | 6 | 15 | 7 | 10 |
| 13 | Albuquerque and Los Alamos, N. Mex. | Supermarket | 1&2 | 6.3 | .7 | 5 | 7 | 5 | 12 |
| 14 | | Supermarket | 1&2 | 6.2 | .6 | 5 | 7 | 5 | 20 |
| 15 | | Supermarket | 1 | N | N | N | N | N | N |
| 16 | | Lumber store | 1&2 | 6.4 | .7 | 5 | 8 | 6 | 25 |
| 17 | Flagstaff, Ariz. | Supermarket | 1&2 | 7.0 | .7 | 6 | 8 | 7 | 18 |
| 18 | | Supermarket | 1&2 | 7.6 | .9 | 6 | 9 | 7 | 18 |
| 19 | | Laboratory | 1&2 | 7.0 | .6 | 6 | 8 | 7 | 13 |
| 20 | | Swimming pool | 2&4 | 8.1 | 1.4 | 6 | 11 | 7 | 22 |
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| 22 | | Supermarket | 1&2 | 6.0 | .9 | 5 | 8 | 7 | 16 |
| 23 | | Supermarket | 1 | N | N | N | N | N | N |
| 24 | | Restaurant | 1&2 | 6.1 | 1.0 | 5 | 8 | 5 | 16 |
| 25 | | Storage shed | 1 | N | N | N | N | N | N |


Figure 1.--Normal occupancy, Class 1 exposure.


Figure 2.--Protected (A) and unprotected (B) exterior exposures, Classes 2 and 3, respectively.

Figure 3.--Special occupancy, Class 4 exposure.

### Development of Moisture Sensor Used in Study

The study was greatly facilitated through the development of a relatively simple and effective moisture sensor (Duff 1966) (fig. 4). This small sensor made it possible to obtain accurate moisture content readings deep in heavy members without impairing their strength or appearance. It can be left in place for repeated readings over extended periods of time.

The probes were calibrated to read moisture content in Douglas-fir at a temperature of 70° F. Thermocouples were installed with the moisture sensors (fig. 5) at each test installation to provide simultaneous data on temperatures within the timbers for appropriate moisture content corrections.

### Installation of Moisture Probes and Thermocouples

To determine possible variations in moisture content within the member, probes were located in the top, middle, and bottom laminates. Thermocouples were installed with the top and middle probes to develop temperature correction data. Probes were also located near an exposed end section and at or near a metal connection to determine any possible effects of these factors on moisture content (figs. 5, 6).

### Duration of Study and Frequency of Observations

To determine any seasonal effects, moisture contents were measured in January, March, June, and September for 3 years. The study was planned to continue for 5 years, but analysis showed the variations were so small that the study could be safely terminated after 3 years.

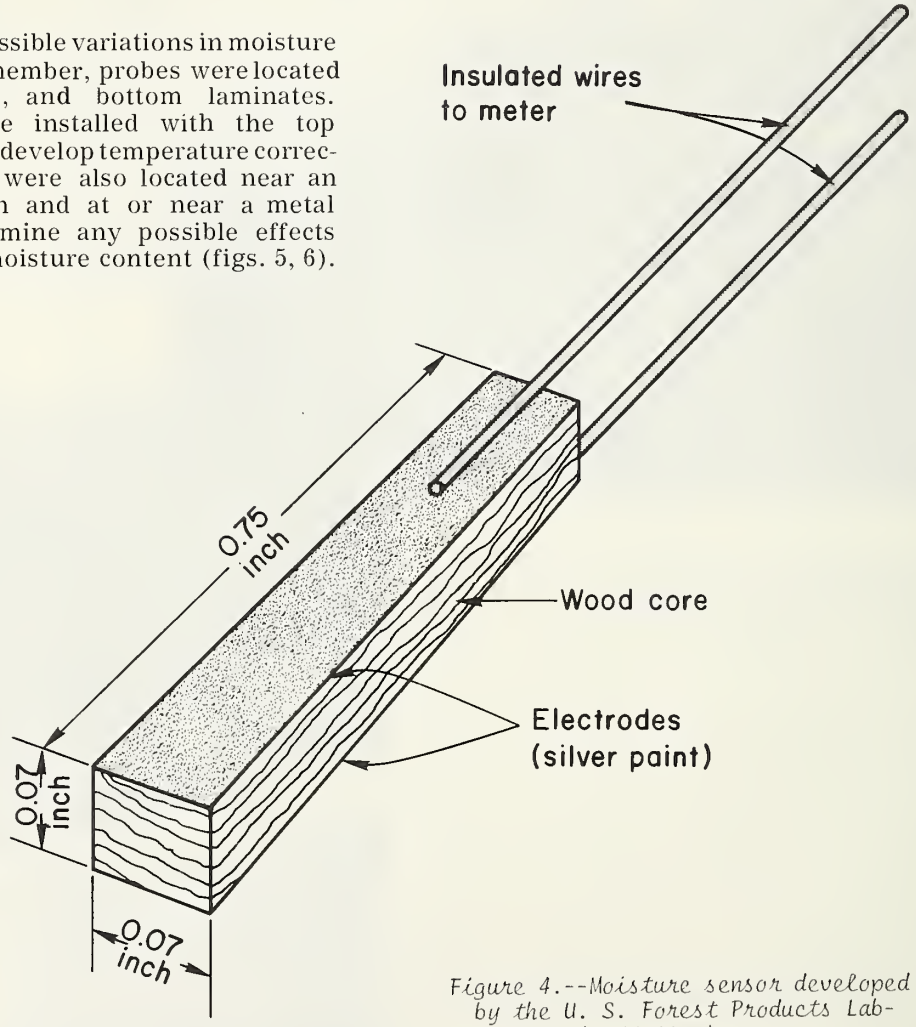



*Figure 4.--Moisture sensor developed by the U. S. Forest Products Laboratory (Duff 1966).*

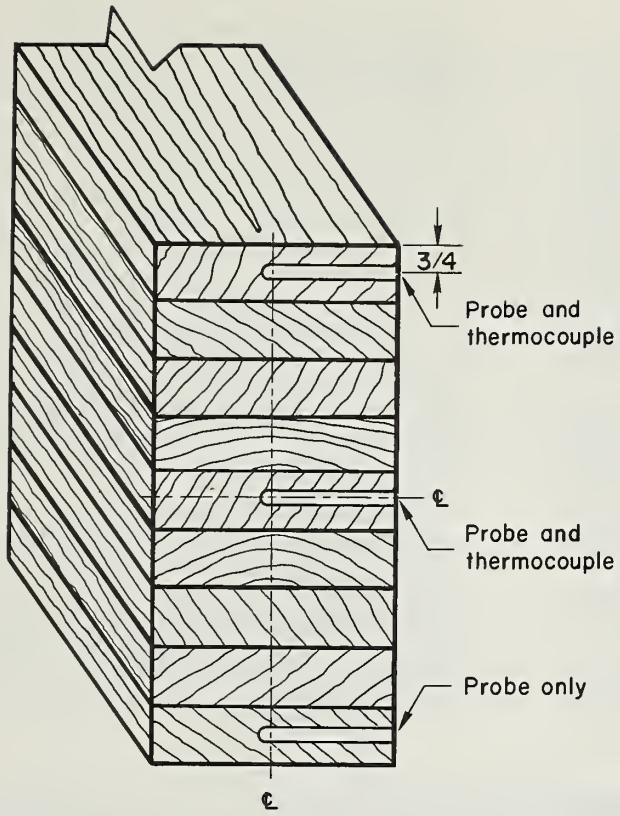
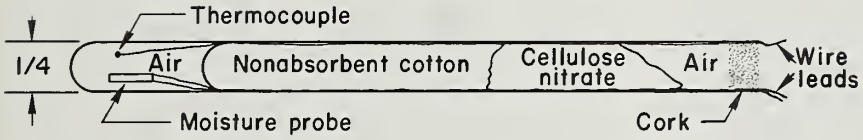



Figure 5.--Typical installation of moisture probes and thermocouples in top, middle, and bottom laminates.



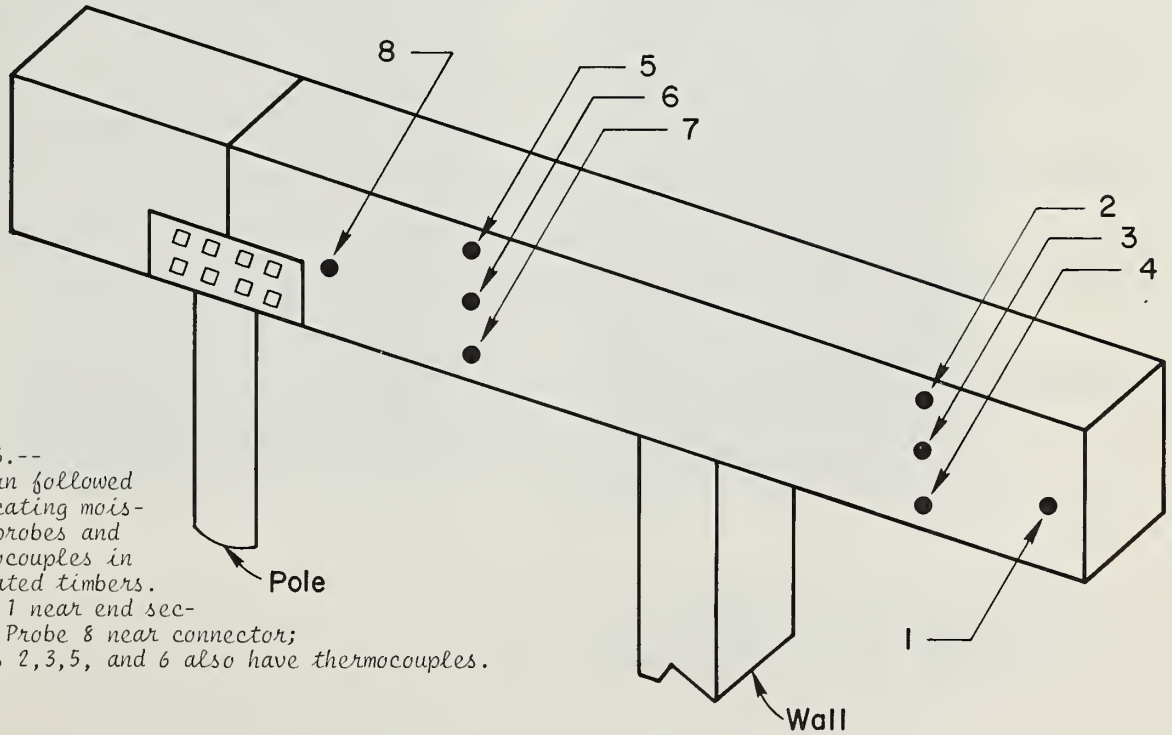




Figure 6.--Pattern followed in locating moisture probes and thermocouples in laminated timbers. Probe 1 near end section, Probe 8 near connector; Probes 2,3,5, and 6 also have thermocouples.

### Analysis and Discussion of Results

All moisture content values were corrected for temperature differences, and summarized by test structure, location, and exposure (table 1) and by date of observation and location of probe within the beam. Analysis showed that the date of observation and location of probe within the timber had no significant effect on moisture content, so these factors were dropped.

The data were also segregated by the four previously defined exposure classes to be more meaningful to laminated timber fabricators (table 2).

Perhaps the most striking result was the very low and extremely narrow range in moisture content found throughout the entire Rocky Mountain region. While it was generally anticipated that moisture content would be low, the remarkably little variation found, especially between interior and exterior exposures, was not expected. The average exterior and interior moisture contents recorded in supermarkets at the different locations in the area (fig. 7) illustrate the relatively uniform EMC condition that apparently prevails throughout the area. The small downward trend of the New Mexico and Arizona locations, while indicative of the relatively warmer and drier climates, is of little practical significance. The increase in indoor moisture content for the Phoenix area is believed to be due to air conditioning.

The slightly higher than average exterior moisture contents shown for structures 6 and 11 (table 1), while of relatively minor magnitude, are nevertheless worthy of further mention since they represent a problem condition common to laminated structures in the area. In both cases, content was high in a short, exposed end section. In both instances the timber was rather severely checked (fig. 8) because of the rapid wetting and drying of the exposed end grain under severe drying conditions.

The degree of checking shown in figure 8 will concern the owners of a structure, and is a very common problem in the Rocky Mountain area, especially in southerly or westerly exposures, because of the high intensity of the sunlight. In some instances metal caps or end coatings have been applied to control or mask the problem.

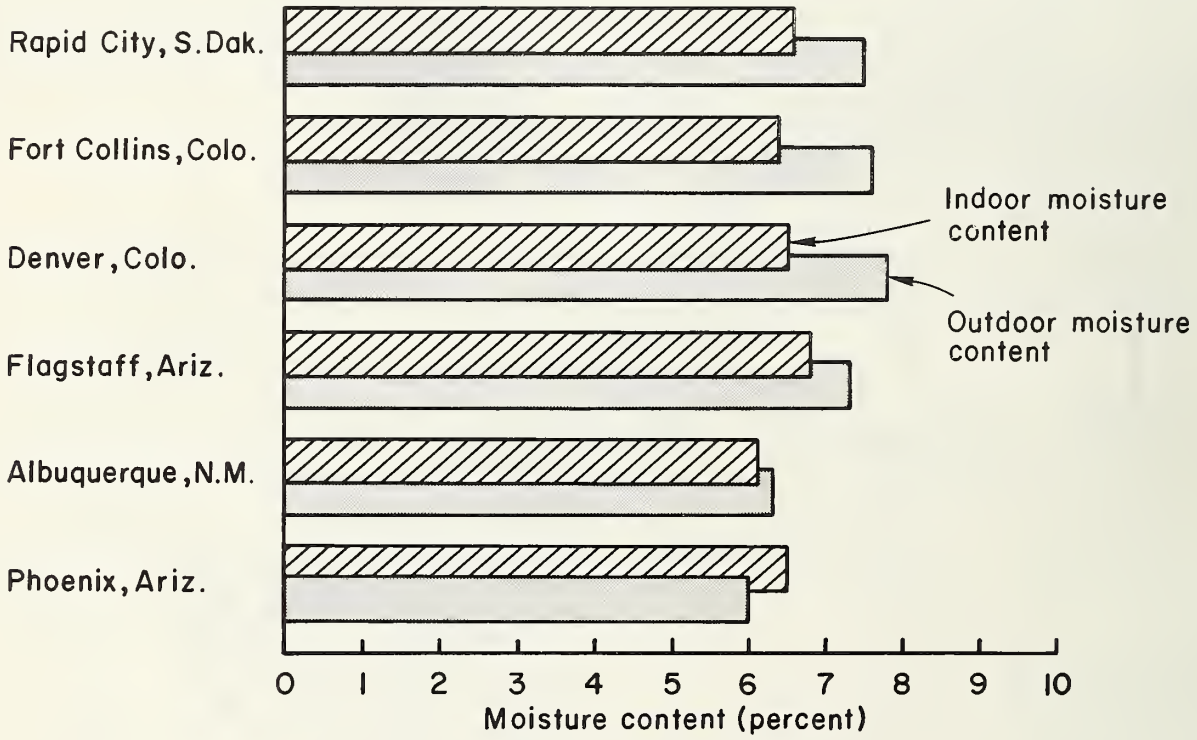



*Figure 7.--Outdoor and indoor moisture contents of laminated timbers in supermarkets in the Rocky Mountain West. Each point is an average of 80 moisture contents (percent of ovendry weight) at two stores.*

Table 2.--Moisture content of laminated timbers in service in the Rocky Mountain area by exposure classes

| | Exposure class | Average | Standard deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| 1 | Interior normal | 6.6 | 0.8 | 5 | 11 |
| 2 | Exterior protected | 7.2 | 1.2 | 5 | 15 |
| 3 | Exterior unprotected | 10.5 | 3.2 | 6 | 19 |
| 4 | Special | 9.3 | 1.0 | 7 | 11 |

*Figure 8.--End section of laminated timber in Test Structure 6 shows severe checking from rapid moisture content changes under exterior unprotected exposure.*

## Conclusions

1. The average equilibrium moisture content (EMC) of laminated timbers exposed to environmental conditions common to the Rocky Mountain area ranges between 6.6 and 10.5 percent.
2. EMC does not vary significantly with season of year or with vertical position in the beam.
3. EMC values of laminated timbers will differ little between interior normal occupancy and exterior protected exposure classes as defined in this report.
4. The higher EMC values associated with end grain in exterior unprotected timbers could likely be reduced through improved design or through the application of effective coatings or covers.
5. The narrow and relatively uniform moisture conditions in the Rocky Mountain region simplify moisture content specification for designers and fabricators of laminated timbers. A simple fabrication moisture content of approximately 8 percent will prove satisfactory for most uses in the area.
6. Because the range of EMC values is low, the area will be less tolerant than most others of any deviation from the prescribed moisture specifications, especially in the high ranges.
7. Southerly and westerly exposures will be especially severe for end sections of laminated timbers. To assure satisfactory performance, designers should avoid such exposures or provide effective protection.
8. Although the study results indicate climatic conditions accurately, higher moisture conditions may exist in specific situations. These situations are generally manmade, however, and usually require special design features such as special coatings or preservative treatments.

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